

Broiler Litter Application Effects on Yield and Nutrient Uptake of 'Alicia' Bermudagrass

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ABSTRACT

Broiler litter should be applied to coincide with crop growth to maximize nutrient uptake. We determined the influence of rate and date of litter application on bermudagrass [*Cynodon dactylon* (L.) Pers.] yield and nutrient uptake. Litter was applied to 'Alicia' hybrid bermudagrass on a Savannah fine sandy loam (fine-loamy, siliceous, semiactive, thermic Typic Fragiudult) at 9 and 18 Mg ha⁻¹ as a single application in early April, May, and June or as a split application in early April and June, May and July, and June and August. Increasing application rate increased yield and P uptake when litter was applied in April [12.8–15.6 Mg ha⁻¹ dry matter (DM); 43.3–49.9 kg P ha⁻¹] or June (14.3–16.9 Mg ha⁻¹ DM; 45.4–51.3 kg P ha⁻¹) but not in May (mean of 15.0 Mg ha⁻¹ DM and 48.4 kg P ha⁻¹). Delaying application of 9 Mg ha⁻¹ until May or 18 Mg ha⁻¹ until June increased annual yield and N, K, and Cu uptake compared with applications in April. Split application improved yield and nutrient uptake only when litter was applied in April and June compared with April application. Phosphorus uptake was unaffected by application date, possibly due to high soil P levels (351 mg kg⁻¹) and to the small quantity of P required by the grass relative to that applied. The results suggest that litter should be applied to bermudagrass only after minimum temperatures exceed those necessary for optimum growth.

APPROXIMATELY 70% of the broiler chickens (*Gallus gallus domesticus*) in the USA in 1999 were produced in Texas, Arkansas, Tennessee, Mississippi, Alabama, Georgia, South Carolina, and North Carolina (Natl. Agric. Stat. Serv., 1999). A large proportion of the approximately 10 million Mg of broiler litter (a mixture of manure, wasted feed, feathers, and wood shavings or other crop residue) produced annually in the region is applied to hay fields and pastures (Bagley et al., 1996). The predominant forage in many of these fields is bermudagrass, a tropical perennial grass that responds readily to applied fertilizer (Overman et al., 1993) and intensive hay harvest management (Overman et al., 1990).

Broiler litter is often applied at rates that meet the N requirement of warm-season grasses in the southeastern USA because the N/P ratio of broiler litter is much lower than the ratio of N and P absorbed from the soil by the grass. Soil P levels on many broiler farms are often several fold greater than those required for maximum forage production. Even though soil nutrient levels may be reduced slowly or remain unchanged due to continued manure application (Kingery et al., 1993), intensive crop production represents an important component of nutrient management. By exporting nutrients in the form of hay from land receiving broiler litter, the rate of nutrient accumulation in the soil and the potential for ground and surface water impairment may be

reduced (Sims and Wolf, 1994). Due to the positive relationship between yield and nutrient uptake (Robinson, 1996), hybrid bermudagrass has the greatest potential among typical perennial forage crops in the southeastern USA to maximize nutrient uptake from heavily fertilized soils.

Daylength and temperature requirements limit optimum growth of bermudagrass to the summer months (Ball et al., 1991). Broiler litter, however, may be applied anytime during the year, depending on the producer's need to remove litter from the poultry house. If litter is applied in early spring, moisture is available for grass growth, but nutrients may be lost in runoff (Sharpley et al., 1994). If litter is applied in the summer, temperatures are more favorable for bermudagrass growth, but N may be lost due to NH₃ volatilization (Brinson et al., 1994; Daniel et al., 1998). Ultimately, litter application should be timed so that nutrient availability coincides with optimum growth of bermudagrass to maximize dry matter (DM) yield and nutrient uptake, and thus minimize the potential loss of nutrients to the environment. Our objective was to determine the influence of date and rate of broiler litter application on yield and nutrient uptake of hybrid bermudagrass.

MATERIALS AND METHODS

The study was conducted in 1997 and 1998 on a farm producing broiler chickens near Mize, MS (31.8° N, 89.6° W), on a Savannah fine sandy loam. The farm is typical of many in the region where broiler chickens have been produced for an extended period and where litter has been applied to bermudagrass on a N basis (a minimum of 9.0 Mg ha⁻¹ yr⁻¹) for the past 25 yr to meet the producer's hay and pasture needs. Before treatments were initiated each year, soil samples were collected in the plot area at 0- to 10- and 10- to 20-cm depth from 20 cores and composited by depth. Soil chemical characteristics were determined using Mehlich-3 extractant (Mehlich, 1984; Table 1). Mean minimum temperature during the 2 yr of the experiment is presented in Fig. 1, and monthly precipitation is presented in Fig. 2.

Plots were established each year on undisturbed Alicia bermudagrass sod on separate but adjacent sites. Broiler litter was hand-applied at 9 and 18 Mg ha⁻¹ (as-is basis) as a single application on 1 April, 1 May, and 1 June or as a split application (equal division of the total) at the same rates on 1 April and 1 June, 1 May and 1 July, and 1 June and 1 August. Fresh litter was obtained from the broiler house on each application date to avoid changes in N concentration caused by composting that occurs during storage (Eghball and Power, 1999). Dry matter of the litter was influenced little by application date (mean of 25%). An 800- to 1000-g subsample of the litter was obtained on each application date and stored at 2°C until nutrient analysis (Table 1). Based on the N concentration of this broiler litter, litter produced elsewhere in the area (34 g kg⁻¹; Sistani et al., unpublished, 2002), and potentially mineralizable N (24.8 g N kg⁻¹ dry litter; Gordillo and Cabrera, 1997),

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Table 1. Chemical characteristics of the soil at the beginning of the experiment (mean of 2 yr) and of broiler litter on each application date.

	pH	N	P	K	Ca	Cu	Fe	Mg	Mn	Zn
			mg kg ⁻¹							
Soil (cm depth)										
0–10	5.8		351	130	769	18	270	85	248	19
10–20	5.9		174	84	445	3	209	79	265	1
		g kg ⁻¹				mg kg ⁻¹				
Litter										
1997										
April	7.4	36	17	33		627				712
May	7.4	36	18	31		624				734
June	7.3	34	18	32		627				832
July	7.2	33	18	27		636				552
August	7.5	34	20	32		681				573
1998										
April	7.2	36	20	37		680				631
May	7.4	32	19	30		596				709
June	7.5	35	21	37		720				664
July	7.3	33	20	34		652				667
August	7.4	33	21	36		724				667

the two application rates provided a medium and high level of N fertilization of the Alicia hybrid bermudagrass (Overman et al., 1993). Initial application dates were chosen to correspond to the period when increasing minimum temperatures favored bermudagrass growth.

The 2- by 6-m plots were arranged in a randomized complete block design (four replicates) with a 1-m alley surrounding each plot. Plots were harvested from 1 June to 1 October on a 30-d harvest interval. If scheduled, litter was applied after harvest. Forage yields were determined by cutting a 1- by 6-m swath at a 7-cm stubble height through the center of each plot with a sickle-bar mower. A 600- to 800-g subsample was taken from each yield sample, dried at 65°C for 48 h, weighed to determine forage DM, and then ground to pass a 1-mm screen. A 50-g subsample of the ground forage was stored in plastic bottles.

Total N concentration of forage was determined by the macro-Kjeldahl procedure (Bremner, 1996). Forage P, K, Cu, and Zn concentration were determined by ashing a 0.8-g subsample in a ceramic crucible at 500°C for 4 h, dissolving the ash in 1.0 mL of 6 M HCl for 1 h and then in an additional 40 mL of a double-acid solution of 0.0125 M H₂SO₄ and 0.05 M HCl for another hour, and then filtering through Whatman no. 1 paper (Southern Coop. Ser., 1983). The P, K, Cu, and Zn concentrations of the filtrate were measured by emission

spectroscopy on an inductively coupled argon plasma spectrophotometer. Nutrient concentration of air-dried litter was measured by the same methods. The pH of the litter was measured in 1:5 litter/water mixture.

Forage nutrient uptake was calculated as the product of DM yield and nutrient concentration at each harvest and summed over all harvests. Efficiency of N and P uptake for the growing season was calculated as total uptake divided by the quantity applied in the litter. Results from both years were combined because year × treatment interactions were not significant ($P \leq 0.05$). Data were subject to analysis of variance, and treatment means were compared by single degree-of-freedom contrasts using SAS (1999).

RESULTS AND DISCUSSION

Application Rate Effects

In both years, increasing the broiler litter application rate from 9 to 18 Mg ha⁻¹ increased annual DM yield of bermudagrass when litter was applied in April (12.8–15.6 Mg ha⁻¹ DM) or June (14.3–16.9 Mg ha⁻¹ DM) but not in May (mean of 15.0 Mg ha⁻¹ DM; Fig. 3 and Table 2). Similar to our results, Wood et al. (1993) mea-

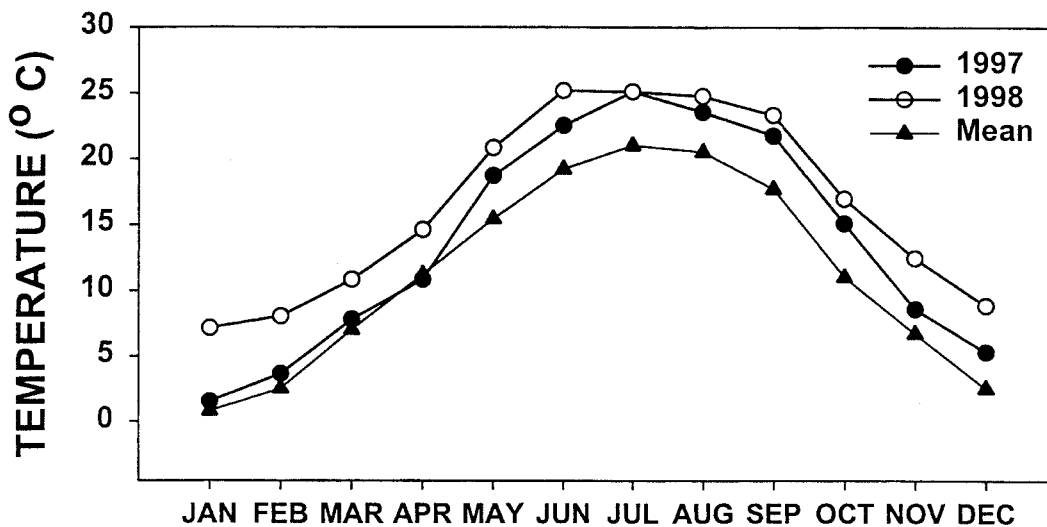


Fig. 1. Mean monthly minimum temperatures for the study period and 30 yr at Mize, MS.

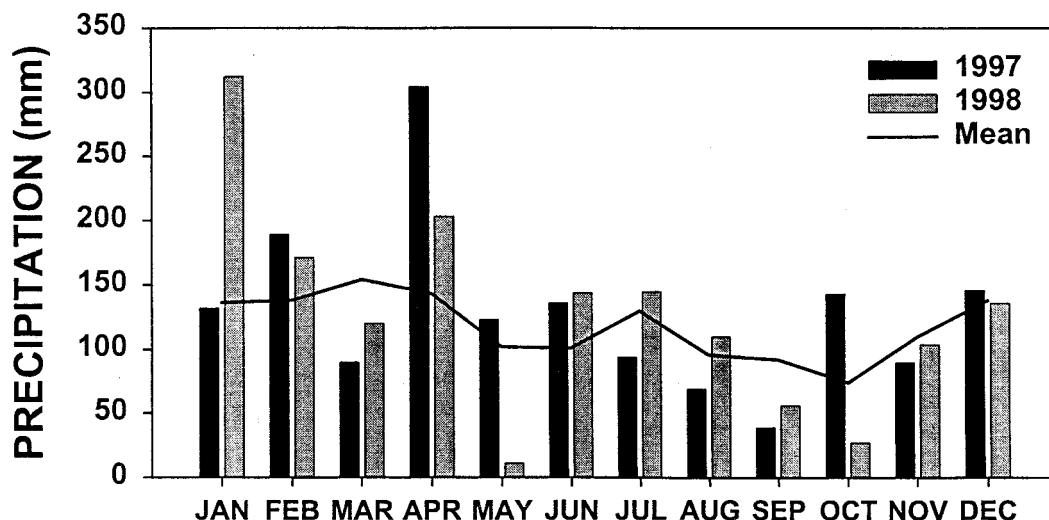


Fig. 2. Total monthly precipitation for the study period and 30 yr mean at Mize, MS.

sured an increase in bermudagrass yield of approximately 20% in North Alabama when the application was increased from 11.2 to 22.4 Mg ha⁻¹.

Despite an increase in mineralizable N applied from approximately 224 to 448 kg ha⁻¹ when the litter rate was increased in May, individual harvest yield of the 9 and 18 Mg ha⁻¹ rate treatments never differed ($P \leq 0.05$). Increasing the application rate from 9 to 18 Mg ha⁻¹ in April increased individual harvest yield each month after application until September. In contrast, increasing the application rate in June increased yield each month until October, a factor producers should consider if attempting to overseed bermudagrass with annual ryegrass (*Lolium multiflorum* Lam.). Bermudagrass fertilized with litter later in the growing season would likely be more competitive with ryegrass seedlings in the autumn than that fertilized earlier.

Similar to annual DM yield, N, P, K, Cu, and Zn uptake increased when litter application rate was increased from 9 to 18 Mg ha⁻¹ in April and June (Fig. 3 and 4; Table 2). Because nutrient concentration of forages generally does not fluctuate as much as forage yield, and nutrient uptake is a product of nutrient concentration and DM yield, this positive association between nutrient uptake and DM yield was expected (Robinson, 1996). Although there was no difference in annual DM yield between the two rates when litter was applied in May, N (Fig. 3), K, and Cu (Fig. 4) uptake also increased (Table 2) when litter application rate was increased from 9 to 18 Mg ha⁻¹ while P (Fig. 3) and Zn (Fig. 4) uptake were unaffected. Greater N, K, and Cu uptake were due to an increase in forage concentration of these minerals, particularly in the first harvest after litter application. Using inorganic fertilizer, Day and Parker (1985) also found that forage N and K concentration increased as application rate increased while P concentration was unchanged. If forage P concentration is unaffected by application rate, P uptake and its export from the land will depend primarily on the producer's ability to maximize DM yield.

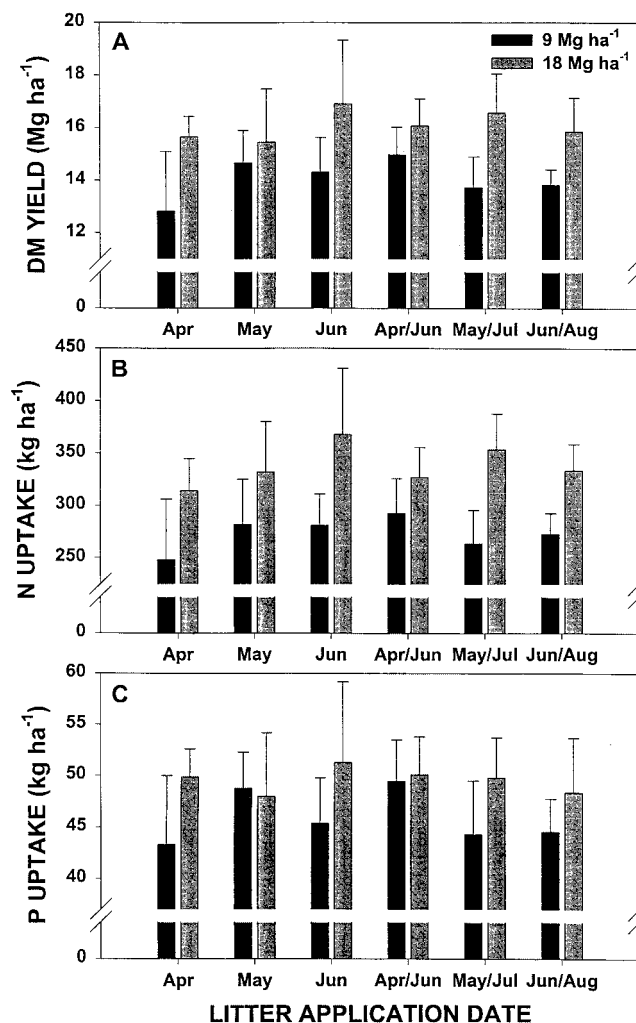


Fig. 3. Annual (A) dry matter (DM) yield and (B) N and (C) P uptake by Alicia hybrid bermudagrass as influenced by date and rate of broiler litter application (mean of 2 yr); see Table 2 for contrasts of treatment means. Error bars indicate standard deviation of the mean.

Table 2. Probability for single degree-of-freedom contrasts of total bermudagrass dry matter (DM) yield and nutrient uptake as influenced by date and rate of broiler litter application (mean of 2 yr).

Application date	Application rate (Mg ha ⁻¹)	DM	N	P	K	Cu	Zn
Application rate contrasts							
Apr.	9 vs. 18	**	**	**	**	**	*
May	9 vs. 18	NS	**	NS	**	*	NS
June	9 vs. 18	**	**	*	**	**	*
Application date contrasts (single application)							
Apr. vs. May	9	*	*	NS	*	*	NS
May vs. June	9	NS	NS	NS	NS	NS	NS
Apr. vs. June	9	*	*	NS	**	**	NS
Apr. vs. May	18	NS	NS	NS	NS	NS	NS
May vs. June	18	*	*	NS	*	*	NS
Apr. vs. June	18	*	**	NS	**	**	NS
Application date contrasts (split application)							
Apr. vs. Apr. and June	9	**	**	*	*	**	*
May vs. May and July	9	NS	NS	NS	NS	NS	NS
June vs. June and Aug.	9	NS	NS	NS	NS	NS	NS
Apr. vs. Apr. and June	18	NS	NS	NS	*	NS	NS
May vs. May and July	18	NS	NS	NS	*	NS	NS
June vs. June and Aug.	18	NS	NS	NS	*	NS	NS

* Means significantly different at the 0.05 level.

** Means significantly different at the 0.01 level.

Application Date Effects

Single Application

Bermudagrass DM yield and N uptake (Fig. 3) and K and Cu uptake (Fig. 4) were increased by applying 9 Mg ha⁻¹ litter in May or June compared with the same rate applied in April (Table 2). Like much of the southeastern USA, minimum temperatures in April at this location (Fig. 1) were less than those required by bermudagrass for optimum root and shoot growth (24–27°C; Beard, 1973). Until temperatures became more favorable for bermudagrass growth, nutrients contained in the litter were not utilized and subject to loss. Although the mineralization rate of litter N in April was likely lower than that reported by Gordillo and Cabrera (1997) due to lower temperatures, it is likely that some N would not be available for uptake when temperatures increased in May due to denitrification losses. At the 9 Mg ha⁻¹ rate, bermudagrass yield and nutrient uptake were similar for May and June applications, suggesting that at this rate, temperature no longer influenced bermudagrass growth. In contrast, P and Zn uptake were not influenced by date of litter application, perhaps due to the high levels of both elements in the soil (Table 1) or the low requirements of bermudagrass for these elements relative to N and K.

In contrast to the 9 Mg ha⁻¹ rate, annual DM yield and N uptake (Fig. 3) and K and Cu uptake (Fig. 4) were increased by applying 18 Mg ha⁻¹ litter in June compared with April or May applications (Table 2). Individual harvest data provide some explanation for these results; first-harvest yield in June from plots receiving litter in April or May was only 500 to 600 kg ha⁻¹ greater than that from plots that had not received litter. In contrast, after litter was applied to the appropriate plots in June, second-, third-, fourth-, and fifth-harvest yields were 300 to 900 kg ha⁻¹ greater than yield from plots receiving litter in April or May. Although

this application rate is considerably greater than that recommended (Bagley et al., 1996), the results are similar to those for the 9 Mg ha⁻¹ rate. Uptake of nutrients contained in broiler litter by bermudagrass is maximized after minimum temperatures are near optimum for growth. Similar to the lower rate, date of application of 18 Mg ha⁻¹ litter had no influence on P and Zn uptake (mean of 49.7 kg ha⁻¹ and 900 g ha⁻¹, respectively).

Split Application

Dividing the 9 Mg ha⁻¹ rate into two equal applications improved annual DM yield and nutrient uptake over a single application only when the April application was split between April and June applications (Fig. 3 and 4; Table 2). Dry matter yield and nutrient uptake were not improved by dividing a May application between May and July or a June application between June and August. These results confirm previous comparisons of application date (April vs. May or June at the 9 Mg ha⁻¹ rate; Table 2) where it was found that bermudagrass yield response was improved by applying litter in May or later because minimum temperatures in April were still below those necessary for optimum bermudagrass growth.

At the 18 Mg ha⁻¹ rate, bermudagrass DM yield and N, P, Cu, and Zn uptake were not improved by splitting the application between any of the months tested (Fig. 3 and 4; Table 2). Apparently the quantity of nutrients supplied by the higher rate applied in April, particularly for N, was sufficient for bermudagrass growth during the remainder of the growing season even though growing conditions were less favorable than those in June when the second half of the split application was made. Only K uptake was improved by splitting the 18 Mg ha⁻¹ application rate due to greater forage K concentration (data not shown).

Our results regarding single vs. split application are

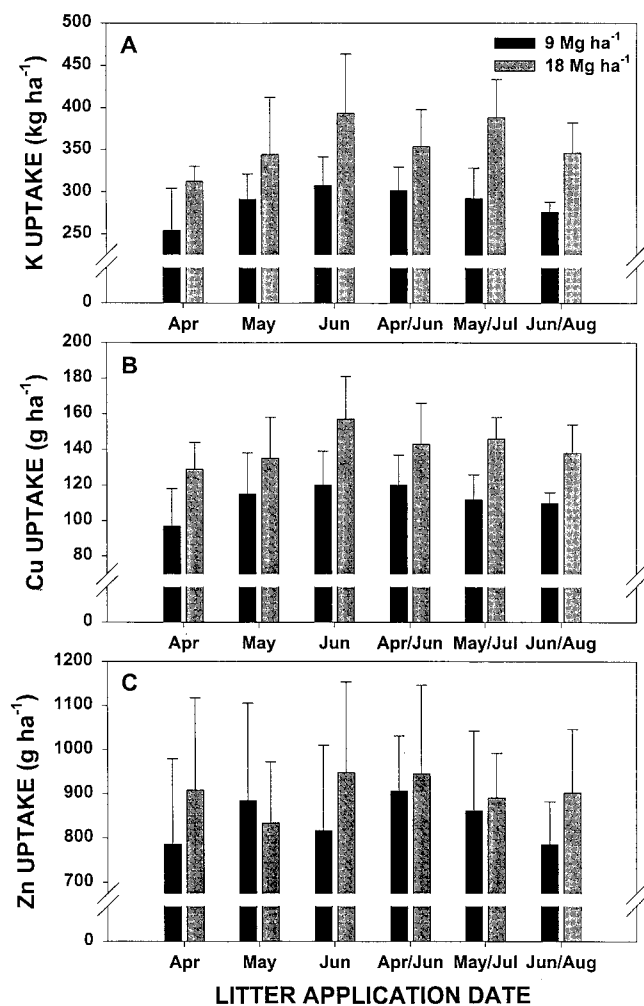


Fig. 4. Annual (A) K, (B) Cu, and (C) Zn uptake by Alicia hybrid bermudagrass as influenced by date and rate of broiler litter application (mean of 2 yr); see Table 2 for contrasts of treatment means. Error bars indicate standard deviation of the mean.

similar to those reported by Evers (1998), who found that applying 9 or 18 Mg ha⁻¹ litter in late spring (30 April or 11 May) increased forage yield 10 to 20% over a split application in late spring and midsummer. In late spring and early summer, soil moisture is generally more favorable for bermudagrass growth, and consequently nutrient utilization, than in late summer.

Efficiency of Nitrogen and Phosphorus Uptake

The requirement of forage grasses for N relative to P (range of 5:1 to 10:1) greatly exceeds the concentration of N relative to P in broiler litter (approximately 2:1; Edwards, 1996). Long-term application of litter to pastures and hay fields contributes to the accumulation of P in the soil because when applied at rates that meet the N requirement of a forage crop, the amount of P applied greatly exceeds that required by the crop. Phosphorus accumulates in the surface soil horizon, and the potential for P loss in runoff to surface waters increases (Sims, 1995).

At both of the application rates used in this study, the quantity of P applied in the litter greatly exceeded that required by the bermudagrass (Kelling and Matocha, 1990). Soil P levels were also high (Table 1) due to previous litter application. The N application rate resulting from the litter application rate thus had a large influence on efficiency of P uptake, or the proportion of P contained in the harvested forage relative to that applied in the litter. Despite relatively aggressive harvest management (30-d harvest interval), efficiency of P uptake ranged from 0.31 to 0.46 at the 9 Mg ha⁻¹ rate and from 0.17 to 0.22 at the 18 Mg ha⁻¹ rate. Based on these estimates of uptake efficiency, litter application rate would have to be <4.5 Mg ha⁻¹ to reduce or stop the accumulation of P in the soil. At the rates used here, soil P levels would continue to increase due to underutilization by the bermudagrass, further increasing the potential for P loss in runoff. In contrast, the proportion of N taken up by the bermudagrass relative to that applied ranged from 1.00 to 1.24 at the 9 Mg ha⁻¹ rate and from 0.64 to 0.76 at the 18 Mg ha⁻¹ rate. Nitrogen uptake efficiencies >1.00 were probably due to the continuing mineralization and uptake of N from litter applied in previous years.

CONCLUSIONS

Although forage crops remove a relatively small quantity of many nutrients relative to the amount often applied in manure, hay production remains an important component of nutrient management. Application of manure to coincide with crop growth to maximize nutrient uptake is an accepted premise. Our results suggest that litter should be applied to bermudagrass only after minimum temperatures exceed those necessary for optimum growth even though the time period in which the grass has to utilize nutrients from the manure is reduced. Unlike N, P uptake was largely unaffected by the application dates chosen here, possibly because soil P levels were high before the experiment began or because bermudagrass requirements for P were relatively low compared with the quantity applied in the litter. Even at the lower application rate, less than half of the P contained in the litter was removed by the bermudagrass.

Split application had no beneficial effect on yield or uptake of N or P unless an initial application of 9 Mg ha⁻¹ made in early spring before bermudagrass growth had begun was instead divided between spring and summer applications. The greatest benefit from split application is that the potential for nutrient transport in runoff is lessened because there is less manure on the soil surface at one time.

REFERENCES

- Bagley, C.P., R.R. Evans, and W.B. Burdine, Jr. 1996. Broiler litter as a fertilizer or livestock feed. *J. Prod. Agric.* 9:342-346.
- Ball, D.M., C.S. Hoveland, and G.D. Lacefield. 1991. Southern forages. Potash and Phosphate Inst. and Foundation for Agron. Res., Atlanta, GA.
- Beard, J.B. 1973. *Turfgrass: Science and culture*. Prentice Hall, Englewood Cliffs, NJ.

- Bremner, J.M. 1996. Nitrogen—total. p. 1085–1122. *In* D.L. Sparks et al. (ed.) *Methods of soil analysis*. Part 3. SSSA Book Ser. 5. SSSA and ASA, Madison, WI.
- Brinson, S.E., M.L. Cabrera, and S.C. Tyson. 1994. Ammonia volatilization from surface-applied, fresh and composted poultry litter. *Plant Soil* 167:213–218.
- Daniel, T.C., A.N. Sharpley, and J.L. Lemunyon. 1998. Agricultural phosphorus and eutrophication: A symposium overview. *J. Environ. Qual.* 27:251–257.
- Day, J.L., and M.B. Parker. 1985. Fertilizer effects on crop removal of P and K in 'Coastal' bermudagrass forage. *Agron. J.* 77:110–114.
- Edwards, D.R. 1996. Recycling livestock manure on pastures. p. 45–64. *In* R.E. Joost and C.A. Roberts (ed.) *Proc. Nutrient Cycling in Forage Syst. Symp.*, Columbia, MO. 7–8 Mar. 1996. Potash and Phosphate Inst. and Foundation for Agron. Res., Atlanta, GA.
- Eghball, B., and J.F. Power. 1999. Phosphorus- and nitrogen-based manure and compost applications: Corn production and soil phosphorus. *Soil Sci. Soc. Am. J.* 63:895–901.
- Evers, G.W. 1998. Comparison of broiler poultry litter and commercial fertilizer for Coastal bermudagrass production in the southeastern US. *J. Sustainable Agric.* 12:55–77.
- Gordillo, R.M., and M.L. Cabrera. 1997. Mineralizable nitrogen in broiler litter: II. Effect of selected soil characteristics. *J. Environ. Qual.* 26:1679–1686.
- Kelling, K.A., and J.E. Matocha. 1990. Plant analysis as an aid in fertilizing forage crops. *In* R.L. Westerman (ed.) *Soil testing and plant analysis*. SSSA Book Ser. 3. SSSA, Madison, WI.
- Kingery, W.L., C.W. Wood, D.P. Delaney, J.C. Williams, G.L. Mullins, and E. van Santen. 1993. Implications of long-term land application of poultry litter on tall fescue pastures. *J. Prod. Agric.* 6:390–395.
- Mehlich, A. 1984. Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. *Commun. Soil Sci. Plant Anal.* 15:1409–1416.
- National Agricultural Statistics Service. 1999. Broiler production by states [Online]. Available at <http://www.usda.gov/nass/aggraphs/brlmap.htm> (verified 27 Mar. 2002).
- Overman, A.R., C.R. Neff, S.R. Wilkinson, and F.G. Martin. 1990. Water, harvest interval, and applied nitrogen effects on forage yield of bermudagrass and bahiagrass. *Agron. J.* 82:1011–1016.
- Overman, A.R., M.A. Sanderson, and R.M. Jones. 1993. Logistic response of bermudagrass and bunchgrass cultivars to applied nitrogen. *Agron. J.* 85:541–545.
- Robinson, D.L. 1996. Fertilization and nutrient utilization in harvested forage systems—southern forage crops. p. 65–92. *In* R.E. Joost and C.A. Roberts (ed.) *Proc. Nutrient Cycling in Forage Syst. Symp.*, Columbia, MO. 7–8 Mar. 1996. Potash and Phosphate Inst. and Foundation for Agron. Res., Atlanta, GA.
- SAS Institute. 1999. SAS/STAT user's guide. Version 8. SAS Inst., Cary, NC.
- Sharpley, A.N., S.C. Chapra, R. Wedepohl, J.T. Sims, T.C. Daniel, and K.R. Reddy. 1994. Managing agricultural phosphorus for protection of surface waters: Issues and options. *J. Environ. Qual.* 23:437–451.
- Sims, J.T. 1995. Characteristics of animal wastes and waste-amended soil: An overview of the agricultural and environmental issues. p. 1–14. *In* K. Steele (ed.) *Animal waste and the land-water interface*. CRC Press, Boca Raton, FL.
- Sims, J.T., and D.C. Wolf. 1994. Poultry waste management: Agricultural and environmental issues. *Adv. Agron.* 52:1–83.
- Southern Cooperative Series. 1983. Reference soil test methods for the southern region of the United States. Bull. 289. Georgia Agric. Exp. Stn., Athens.
- Wood, C.W., H.A. Torbert, and D.P. Delaney. 1993. Poultry litter as a fertilizer for bermudagrass: Effects on yield and quality. *J. Sustainable Agric.* 3:21–36.